An Evaluation of Generic Output Profiles for n-Color Printing

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Abstract

Generic Output Profiles (GOP) allow one to create new profiles for various ink sets by substituting colors into existing multi-channel characterization data. This study was designed to investigate whether or not generic output profiles could perform color conversions as accurately as profiles made from full characterization press runs. The study was conducted using a digital halftone printer and a waterless offset lithographic press, in which ICC profiles were created for each device from full characterizations conducted with various colorant sets (including 293 Pantone Blue, Pantone Warm Red, and Hexachrome Orange in addition to cyan, magenta, yellow and black) and generic output profiles were created by substituting the various spot colors into previously run baseline characterizations of cyan, magenta, yellow and black.

Test targets comprised of various color swatches in Adobe98 RGB were converted with each of the ICC profiles and the generic output profiles. The printed color patches were measured and CIE ΔE_{2000} values were calculated between the generic output profiles and their corresponding ICC profiles built from full characterizations. It was determined that generic output profiles with one- and two-color substitutions performed color conversions nearly as well as the fully characterized profiles, with an average ΔE_{2000} of less than 0.5 difference in color conversion accuracy. The digital proofer study demonstrated that in the case of a three-color substitution, the GOP workflow was less accurate by 4.17 ΔE_{2000}.

Introduction

Printers involved with producing product packages and labeling are continually striving to manage their customer's brand colors throughout the print manufacturing process. High-end packaging graphics often require 6–8 colors in order to achieve acceptable product photography reproductions and to reproduce brand colors in line art graphics and corporate logos. Typically, printers use traditional process colors (cyan, magenta, yellow and black) for the photographic reproductions, plus 1–4 line colors for brand colors and logos, adding substantial cost increases for the production of printed packages.

To reduce these costs, it is sometimes effective to remove one or more process colors and substitute them with line colors. Numerous printers have been successful using "modified" process colors in packaging applications. Extensive trial and error and manual color separation was

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required, but the end results have proven to save costs to the printer and provide high quality results to the print buyer. Current color management technologies provide enhanced opportunities to build multi-channel, or n-color, ICC profiles that provide efficient and predictable multi-color separations and the opportunity to output digital proofs using traditional CMYK process inks. These n-color profiles are created from data derived from full characterization runs utilizing the various spot colors required for the particular package. Printing the characterization targets requires precise methodology and process control, and uses valuable press time at the expense of production.

New technology in the form of Generic Output Profiles (GOP) from X-Rite's ProfileMaker® offers even greater practicality by allowing one to build customized n-color profiles from previous characterization data by simply replacing colors in each channel to create alternative process color sets (Black, 2006). The GOP technology has the considerable advantage of not requiring a customized characterization for every ink set combination. Once a baseline, multi-channel characterization has been conducted, one can substitute any number of colors for another and create generic output profiles from the baseline data without the expense of conducting multiple characterizations or sacrificing production time.

The current research was undertaken to evaluate whether or not profiles created using GOP technology could perform as well as n-color profiles created from custom press characterizations. Experiments were performed on two printing systems, a Latran Prediction 1420 Imager and a Heidelberg QuickMaster DI. In each experiment, the printing system was characterized using standard CMYK process sets to serve as the baseline for GOP color substitutions and also using customized characterization runs with color sets comprised of one, two or three colors in place of cyan, magenta and yellow. It was hypothesized that differences would be found between the converted, printed images using custom characterizations and GOP workflows.

Methodology

The initial study was conducted using a Latran Prediction 1420 Imager. The Latran Prediction system allows one to produce digital proofs using alternative ink sets. The Prediction Imager uses ink sheets that are ablated with a laser to create a digital halftone for each color printer (Latran Technologies, 2002); Latran produces a number of CMYK ink sheets for various densities as well as a limited number of spot colors. The imaged ink sheets are then laminated to a proofing medium to create a composite, digital halftone proof. The digital imager was ideal for producing a number of custom characterizations in a relatively short amount of time.

The Latran study involved a series of color substitutions into a baseline characterization using Latran's cyan, magenta, yellow, and black ink sheets. First the CMYK characterization was created using a customized multi-channel target created with MeasureTool® 5.07 target generating software. The GOP substitutions must be made with a multi-channel profile rather than a traditional CMYK target (Black, 2006). Next, customized, multi-channel targets were created in MeasureTool® for the following ink sets: Pantone 293 Blue, magenta, yellow and black; Pantone 293 Blue, Pantone Warm Red, yellow and black; and Pantone 293 Blue, Pantone Warm Red, Hexachrome Orange and black. These custom characterizations would represent systematic substitutions of one, two and three colors for cyan, magenta and yellow.

The baseline CMYK and the three custom characterizations were imaged on the Latran Prediction Imager and measured using an X-Rite DTP70 spectrophotometer interfaced with MeasureTool®. From these fully characterized data sets, four ICC profiles were created with ProfileMaker® 5.07 software. Next, the baseline CMYK characterization data was opened via the GOP option in ProfileMaker® and three generic output profiles were created with the following substitutions—1: Pantone 293 for cyan, 2: Pantone 293 Blue for cyan and Pantone Warm Red for magenta, and 3: Pantone 293 Blue for cyan, Pantone Warm Red for magenta, and Hexachrome Orange for yellow. In this manner, the experiment systematically replaced one, two and three colors from the four-color system, leaving the achromatic black in all four profiles. Table 1, Latran Ink Sheet Sets, shows the custom characterizations.

Table 1. Latran Ink Sheet Sets

Baseline	Cyan	Magenta	Yellow	Black
1 Substitution	Pantone 293 Blue	Magenta	Yellow	Black
2 Substitutions	Pantone 293 Blue	Pantone Warm Red	Yellow	Black
3 Substitutions	Pantone 293 Blue	Pantone Warm Red	Hexachrome Orange	Black

In addition to the ICC profiles created from each of the custom characterizations, generic output profiles were created by substituting each of the spot colors in the ProfileMaker® software. The substitution can be accomplished by measuring either simply a solid color swatch of the spot color or a 10-step tone scale (Black, 2006); 10-step grayscales were used to create the generic output profiles in this study. ProfileMaker® can then substitute that color for another used in the baseline characterization and create a profile for the new color set. Generic Output Profiles were created with the same substitution scheme as illustrated in Table 1.

To test how well the generic output profiles would match the custom characterizations, an RGB test target comprised of 759 color swatches was converted from Adobe98 RGB to each of the custom ink sets using both GOP and n-color workflows. The converted images were then output on the Latran Prediction Imager and measured with the DTP70. Initially, the experiment was designed to see if the GOP workflow could serve as a predictor of the performance of a fully characterize, n-color profile. To that end, the data between each of the matching ink sets were compared using CIE ΔE_{2000}. Table 2, GOP vs. ICC Color Differences, shows the average ΔE_{2000} between the printed, converted targets for both the custom characterizations and their GOP counterparts to illustrate whether or not they would perform in the same way.

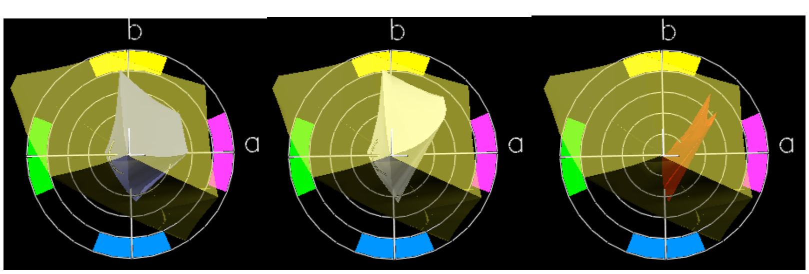
Table 2. Substitution Color Differences (ΔE_{2000})

1 Substitution	2 Substitutions	3 Substitutions
293 Blue, Magenta, Yellow, Black	293 Blue, Warm Red, Yellow, Black	293 Blue, Warm Red, Hex Orange, Black
1.98	3.34	6.90

It appears from the data in Table 2 that the ability of the generic output profiles to model the behavior of the profiles built from full printer characterizations decreases as the number of substitutions increases. A more pressing question, however, is how the two workflows compare in successfully converting the colors from the original Adobe98 RGB file to print. To determine this, the CIELAB values of the digital file were compared to the printed LAB values of the GOP and fully characterized profiles. The CIE ΔE_{2000} values were averaged and are shown in Table 3, Latran Study Profile Conversion Accuracy. It should be noted that the conversions are occurring between the full Adobe98 RGB color space to the relatively limited color spaces of Blue, Red, Orange and Black colorants, so the ΔE values presented are rather high, but many of the original colors are considerably out of the printer gamut. Figure 1, Color Gamut Comparisons, shows the range of color swatches rendered in Adobe98 RGB and each of the color gamuts of the modified process ink sets.

Table 3. Latran Study Profile Conversion Accuracy (ΔE_{2000})

1 Substitution		2 Substitutions		3 Substitutions	
GOP	ICC	GOP	ICC	GOP	ICC
Blue, M, Y, K	Blue, M, Y, K	Blue, Red, Y, K	Blue, Red, Y, K	Blue, Red, Orange, K	Blue, Red, Orange, K
13.86	13.39	15.23	15.18	23.95	19.78



Adobe 98 & BMYK Adobe 98 & BRYK Adobe 98 & BROK

Figure 1. Color Gamut Comparisons

Following the Latran study, it was decided that the experiment should be performed in a production environment rather than another proofing scenario. To this end, press runs were conducted on a four-color Heidelberg QuickMaster DI waterless offset lithography press. First, a baseline KCMY characterization was performed, and then the press was characterized using a modified process set of Black, Pantone 293 Blue, Pantone Warm Red, and Yellow, thus replicating the two-color substitution of the Latran study. As before, ProfileMaker® 5.07 software was used to create the generic output profiles by measuring tint scales of the Pantone 293 Blue and Pantone Warm Red in order to substitute them for cyan and magenta, respectively, from the baseline KCMY characterization data. An RGB testform was created in MeasureTool® and Adobe98 RGB color space was assigned to the RGB file. The 391 color swatches were converted using both the ICC profile created from the full press characterization and the generic output profile created from the substitution data. Press densities were carefully matched to the KBRY characterization run and balanced across the sheet. The converted targets from each of the profiles were printed side-by-side on the press sheet. Once the sheets had dried, a DTP70 spectrophotometer was used to measure CIELAB values from six randomly selected press sheets, which were then averaged together. The printed targets from each of the profiles were compared to each other and to the LAB values of the Adobe98 RGB test target using CIE ΔE_{2000}. The results are shown in Table 4, Litho Study Color Conversion Comparisons.

Table 4. Litho Study Color Conversion Comparisons (ΔE_{2000})

Full Characterization vs. GOP substitutions (comparing printed sheets converted with each profile)	Full Characterization Conversion Accuracy (comparing print to RGB)	GOP Conversion Accuracy (comparing print to RGB)
3.60	15.18	14.77

Results and Discussion

In the Latran study, spot colors were incrementally substituted into the baseline CMYK characterization data set such that one-, two- and three-color substitutions were tested using generic output profiles to perform color conversions from Adobe98 RGB to each of the modified process color sets. For comparison, the same color conversions were performed using ICC profiles created from full characterization runs of each of the modified process sets. The data indicates that the generic output profiles performed comparably to the ICC profiles generated from full characterizations. With the single-color substitution and the two-color substitution, the generic output profiles converted the color swatches from Adobe98 RGB almost as accurately as the ICC profiles from the full characterizations, within an average of 0.47 ΔE_{2000}, a small difference. When the third substitution color was introduced, the GOP workflow was less accurate than the full characterization by an average of 4.17 ΔE_{2000}.

It is interesting to note that while the one- and two-color substitutions were within an average 0.47 ΔE_{2000} and 0.05ΔE_{2000}, respectively, when converting from Adobe98 RGB to the modified process sets, they differed in how they rendered each swatch to a much greater degree, on average 1.98 ΔE_{2000} for the one-color substitution and 3.34 ΔE_{2000} for the two-color substitution. This suggests that while the overall performance is similar, they arrive at very different solutions for each color conversion. This discrepancy becomes more significant if the data is broken out to the greatest differences between the two sets of profiles. For the single-color substitution, the greatest 10% ΔE_{2000} was 5.68; for the two-color substitution, the greatest 10% ΔE_{2000} was 9.94; and for the three-color substitution, the greatest 10%ΔE_{2000} was 24.42.

The production run on the Heidelberg QuickMaster DI gave very similar results to the Latran study. In both cases, a substitution of Pantone 293 Blue for cyan and Pantone Warm Red for magenta was employed. In the production run, the difference between how the generic output profile and the fully characterized profile performed was minor, 0.41ΔE_{2000}. This is consistent with the performance of the one- and two-color substitutions in the Latran study; however, in this instance, the generic output profile slightly outperformed the fully characterized profile. Further, the difference between the ways each of the Heidelberg profiles rendered the color swatches was 3.60 ΔE_{2000}, as compared to the 3.34 ΔE_{2000} of the Latran two-color profiles.

Conclusions

The results of this study indicate that generic output profiles, which allow one to substitute colors into an existing set of characterization data, can, on average, perform color conversions as accurately as a profile created from a full characterization, as long as only one or two colors are substituted. This technology provides a valuable tool for creating n-color profiles without the expense of custom characterization runs for each set of colors. Interested printers may use this data to decide if the differences are acceptable given the convenience and cost savings afforded by GOP technology.

Suggestions for Further Study

The subject of n-color process sets through GOP workflows provides a number of interesting areas for future study. For instance, how much impact does the difference in hue angle have on the success of a color substitution? What would be the impact of only entering the solid color instead of data from a 10-step grayscale? In addition to ink substitutions, what is the potential for building generic output profiles for substrate substitutions or changes in tonal value increase due to anilox roll changes?

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